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(54) SHIM TRAY, AND GRADIENT COILS SYSTEM AND MAGNETIC RESONANCE APPARATUS FOR THE ACCEPTABLE OF THE SHIM TRAY

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(30) **Foreign Application Priority Data**

Mar. 28, 2002 (DE) 102 14 111

(51) **Int. Cl.**[7] **G01V 3/00**
(52) **U.S. Cl.** **324/319**; 324/318
(58) **Field of Search** 324/319, 318, 324/322, 309, 307, 320; 128/653; 335/296

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,349,297	A		9/1994	DeMeester et al.	324/319
5,389,909	A		2/1995	Havens	324/319
5,532,597	A	*	7/1996	McGinley et al.	324/319
5,635,839	A	*	6/1997	Srivastava et al.	324/320
5,786,695	A	*	7/1998	Amor et al.	324/320
6,011,394	A	*	1/2000	Petropoulos et al.	324/318

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WO	WO 88/08126	10/1988

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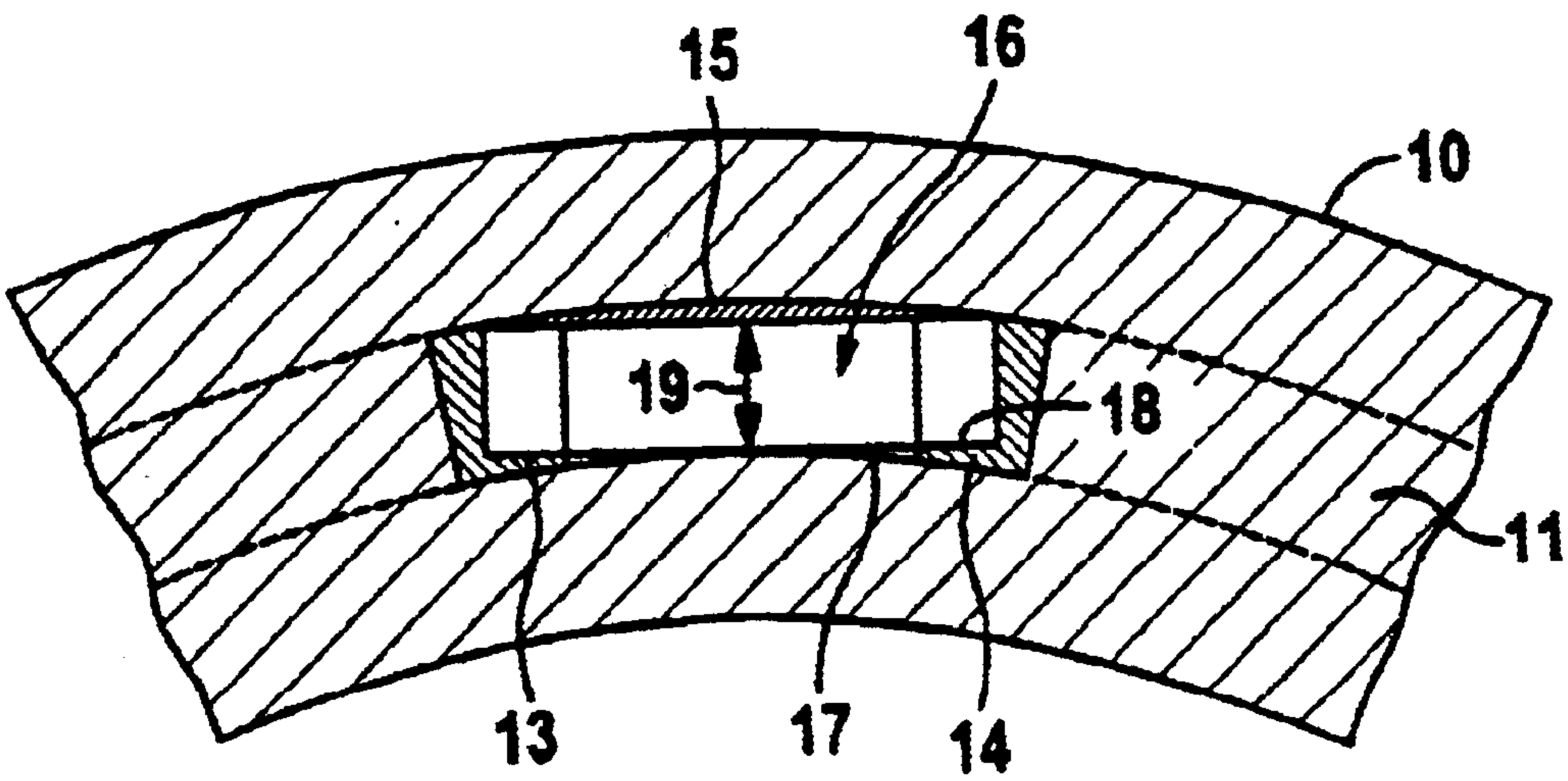
(57) **ABSTRACT**

In a shim tray, a gradient coil system and a magnetic resonance apparatus for the acceptance of the shim tray, the shim tray is sub-divided, in the direction of insertion into the gradient coil system or the magnetic apparatus into at least two sub-boxes that can be released from one another.

6 Claims, 4 Drawing Sheets



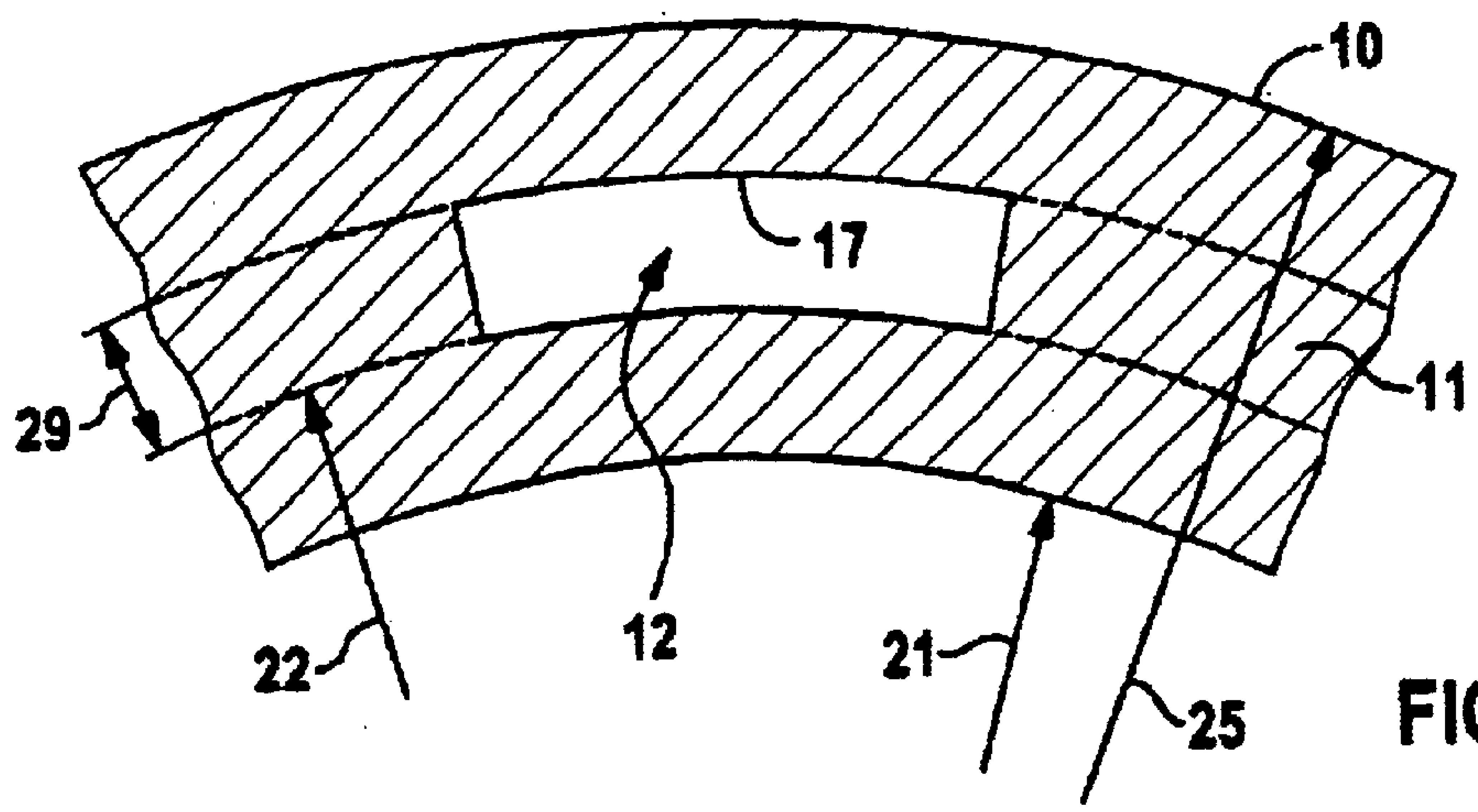


FIG 1

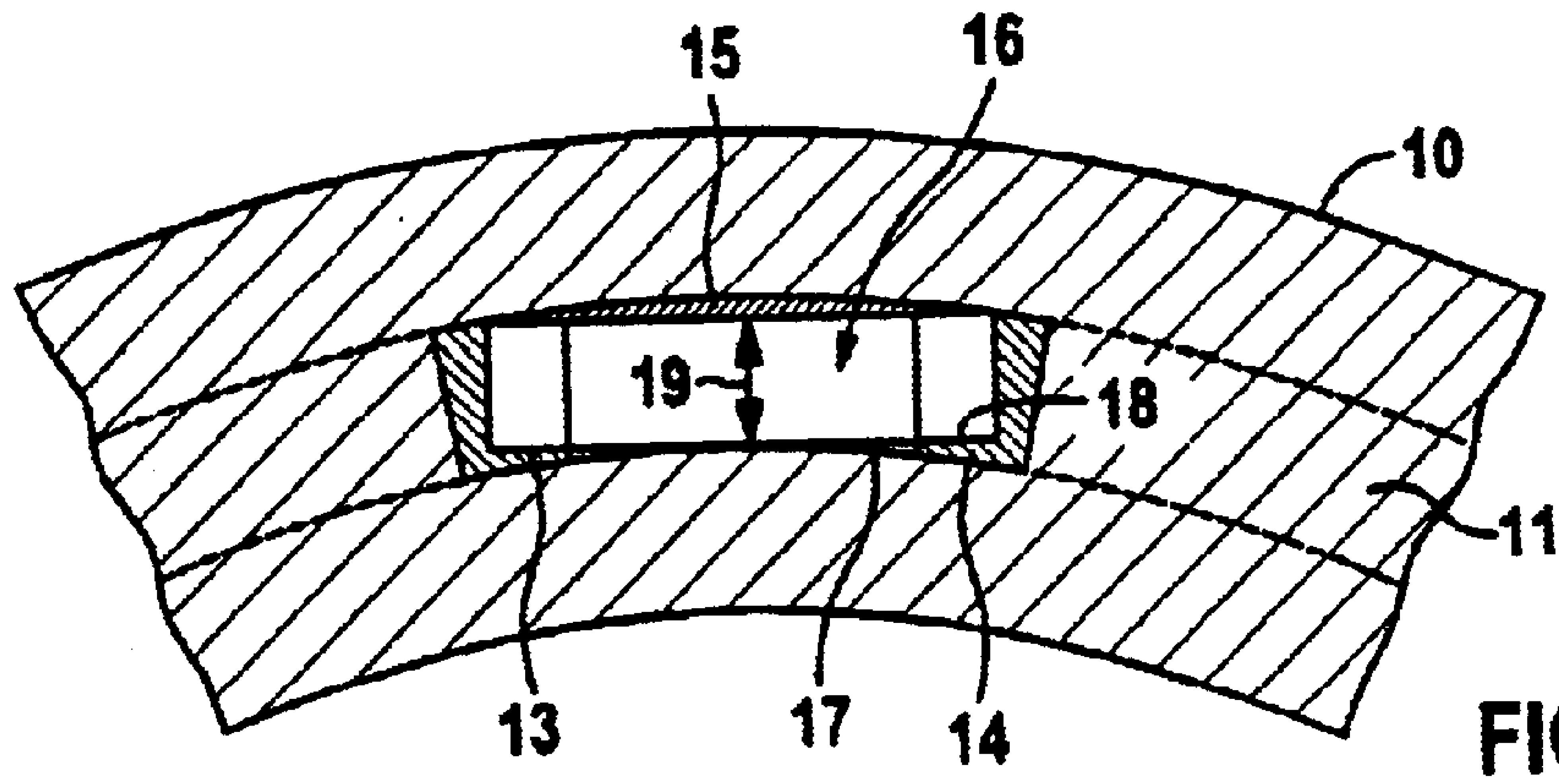


FIG 2

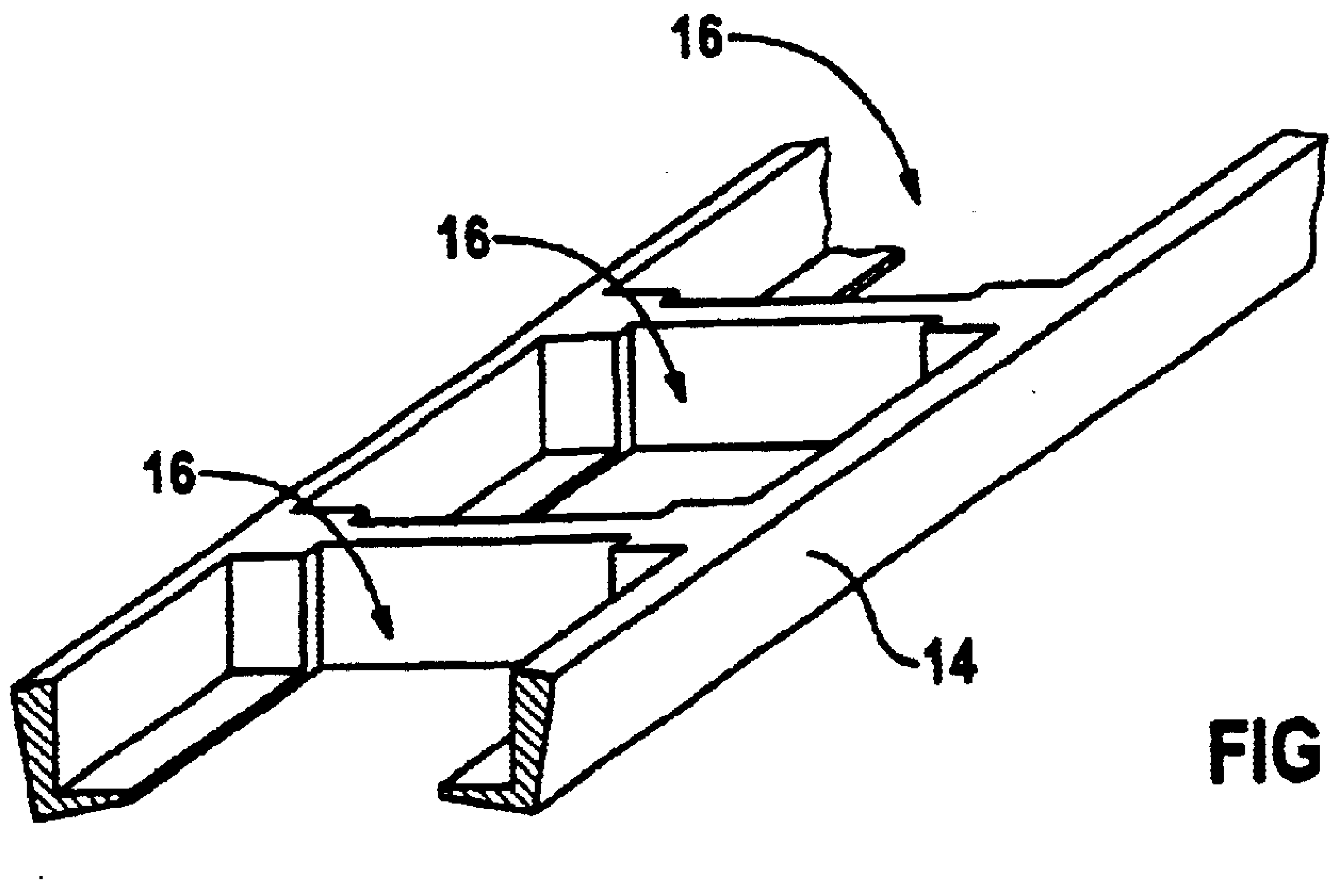


FIG 3

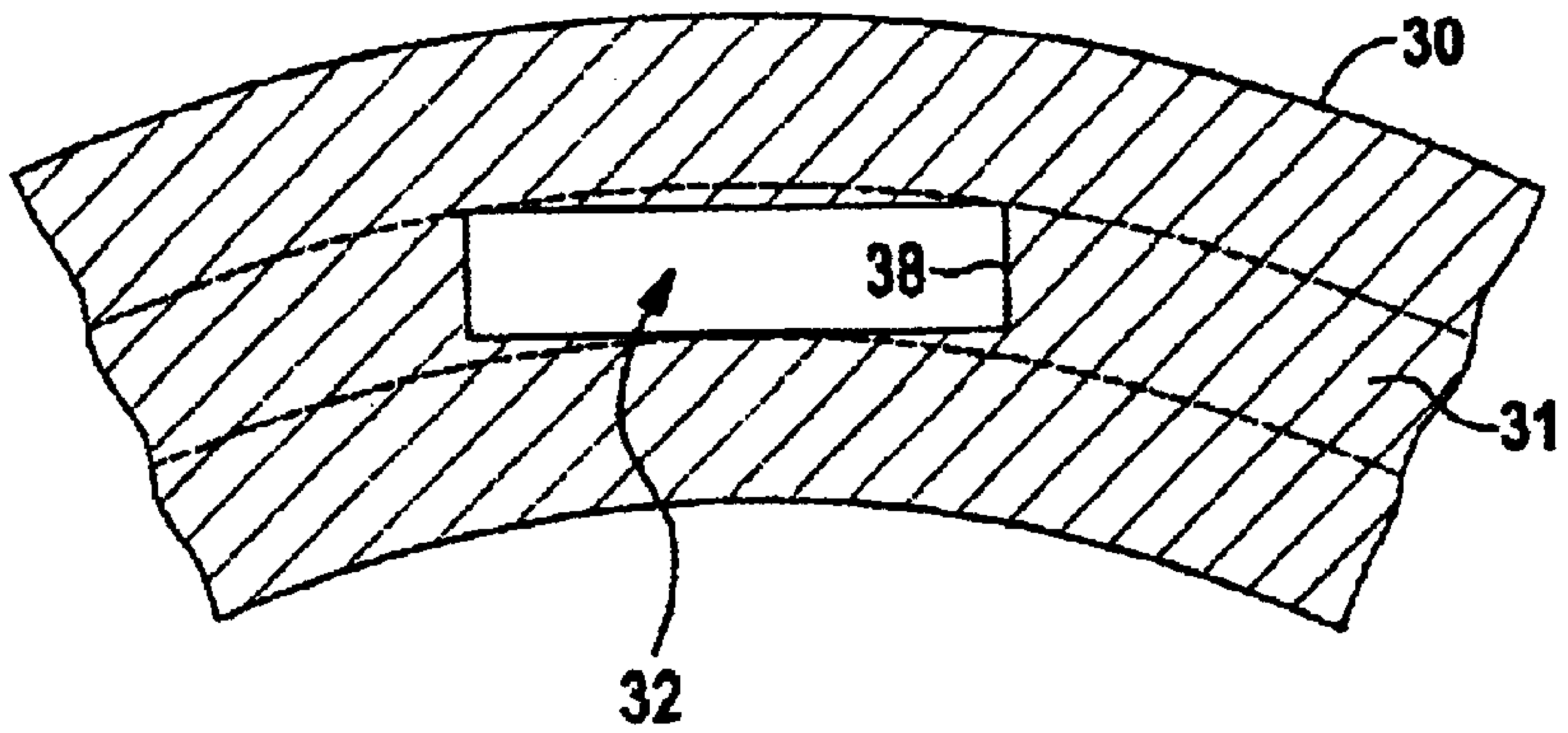


FIG 4
(PRIOR ART)

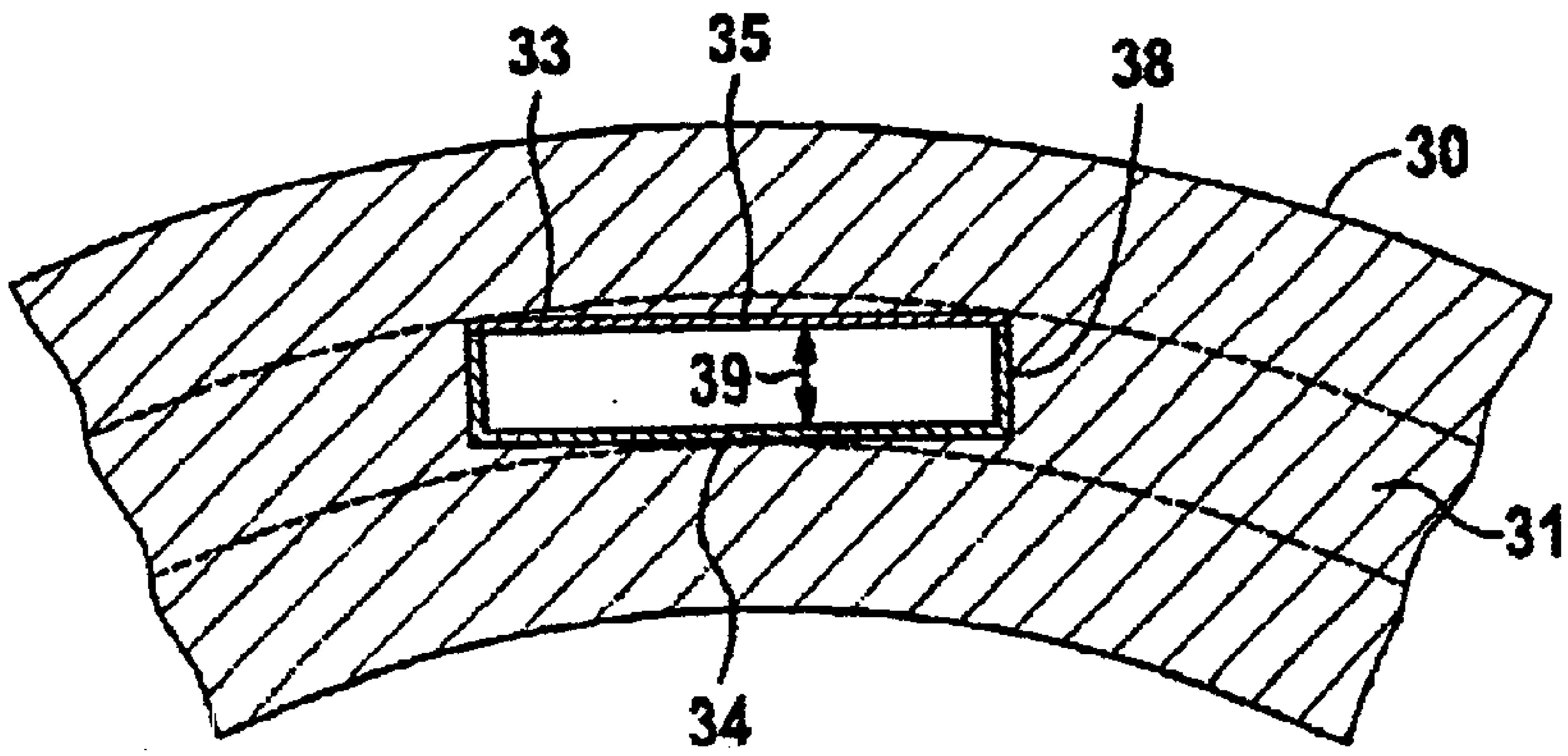


FIG 5
(PRIOR ART)

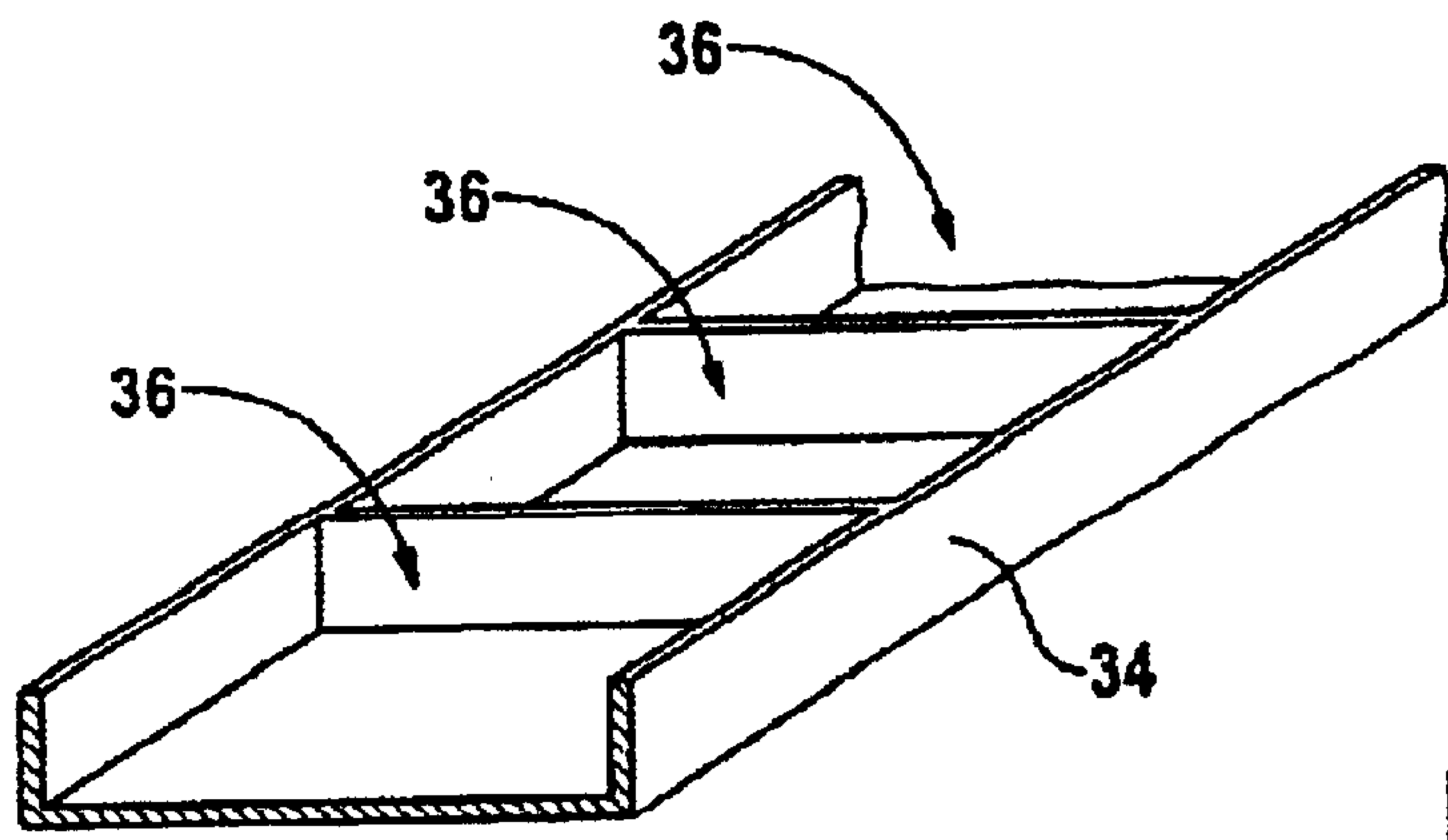


FIG 6
(PRIOR ART)

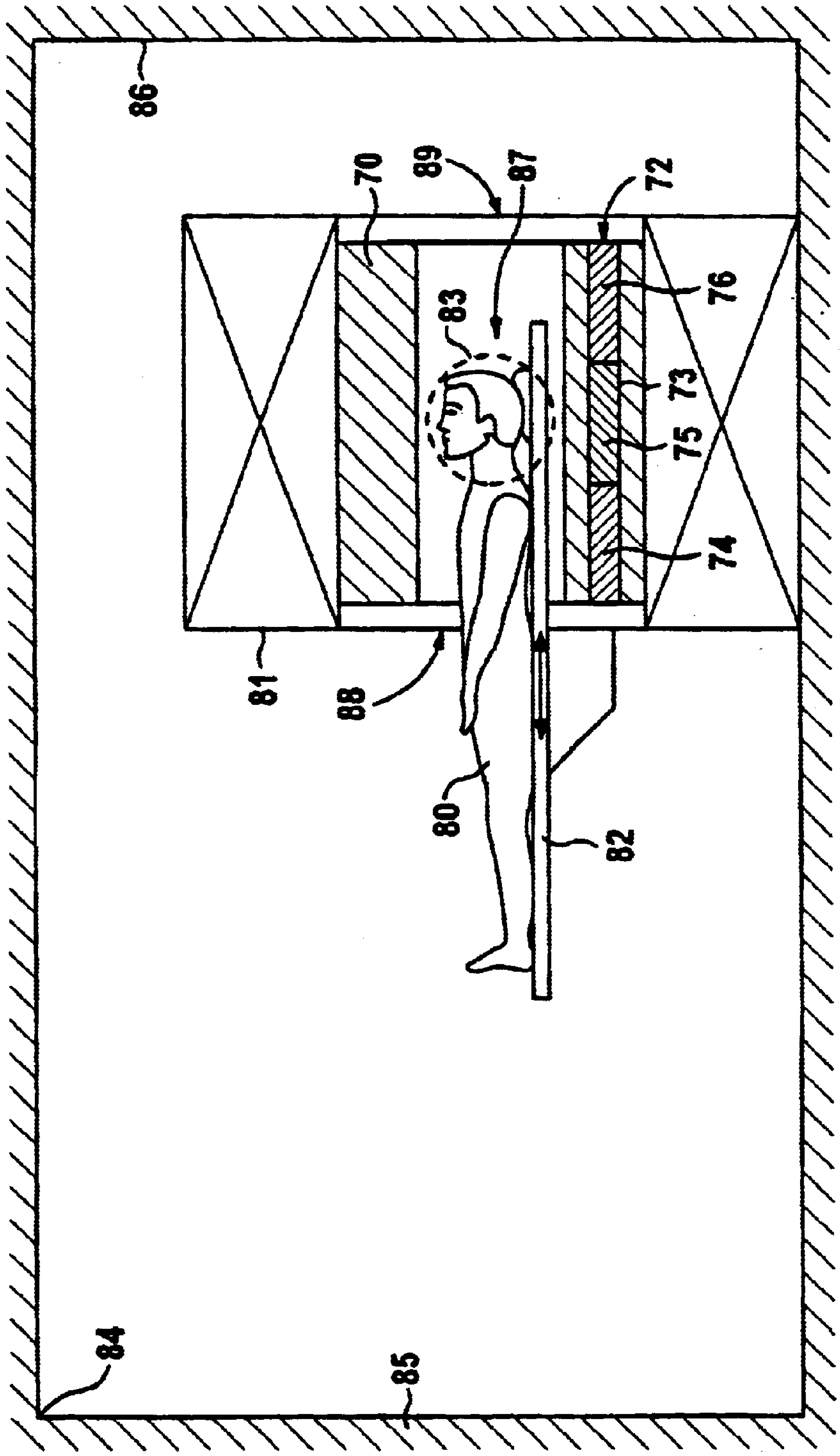


FIG 7

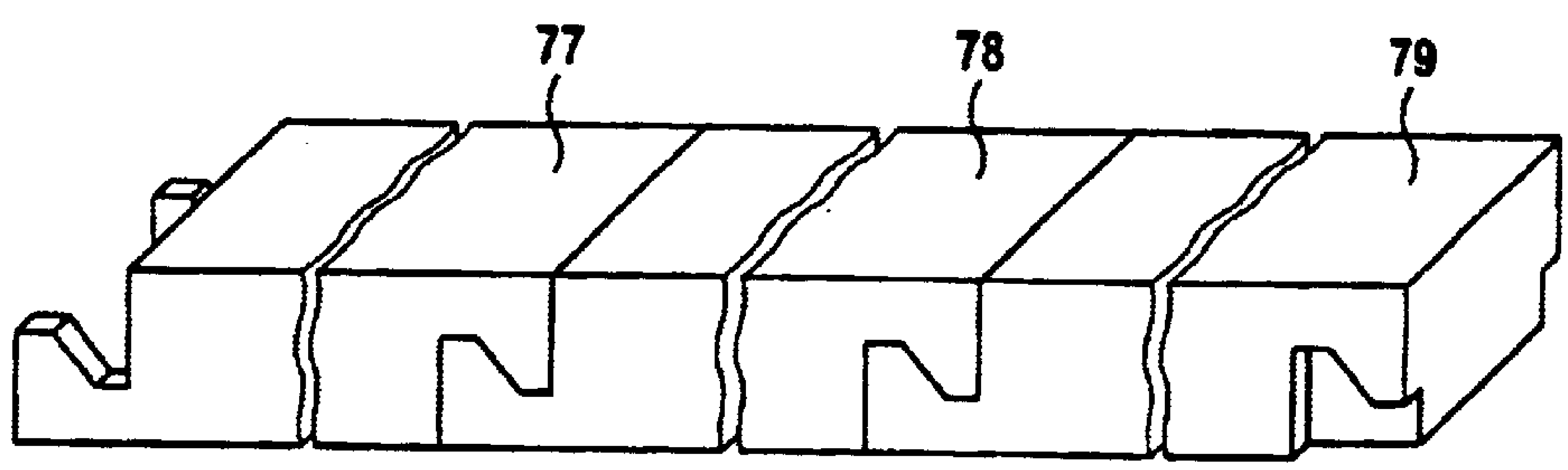


FIG 8

SHIM TRAY, AND GRADIENT COILS SYSTEM AND MAGNETIC RESONANCE APPARATUS FOR THE ACCEPTABLE OF THE SHIM TRAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a shim tray for holding laminae of a passive shim system for a magnetic resonance apparatus. The invention also is directed to a gradient coils system for accepting such a shim tray, as well as to a magnetic resonance apparatus for accepting such a shim tray.

2. Description of the Prior Art

Magnetic resonance technology is a known technology for, among other things, acquiring images of the inside of the body of an examination subject. In a magnetic resonance apparatus, rapidly switched gradient fields that are generated by a gradient coil system are superimposed on a static basic magnetic field that is generated by a basic field magnet. The magnetic resonance apparatus also has a radio-frequency system that emits radio-frequency signals into the examination subject for triggering magnetic resonance signals and picks up the magnetic resonance signals, on the basis of which magnetic resonance images are produced.

A high homogeneity of the basic magnetic field is an important factor for the quality of the magnetic resonance images. Inhomogeneities of the basic magnetic field within a homogeneity volume of the magnetic resonance apparatus cause geometrical distortions of the magnetic resonance image that are proportional to the inhomogeneities. The fat-water separation is also important in this context. An RF pulse without gradient activation is emitted at the frequency of the hydrogen in the fat. The protons excited in this way only slowly return back into the field direction and therefore cannot be re-excited for a certain time. Images acquired during this time thus shown no fat but only water. To this end, however, the homogeneity in the imaging volume must be better than 1 ppm peak—peak since the distance of the fat line from the water line amounts to approximately 3 ppm. Arrangements referred to as shim systems are employed for improving the basic magnetic field homogeneity within the homogeneity volume. A distinction is made between passive and active shim systems. In a passive shim system, a number of laminae composed of a magnetic material, particularly a ferromagnetic iron alloy, are attached in the examination space of the magnetic resonance apparatus in a suitable arrangement. To that end, the basic magnetic field is measured within the homogeneity volume before the attachment of the laminae. Using the measured values, a computer program determines the suitable number and arrangement of the laminae.

For example, U.S. Pat. No. 5,635,839 discloses a hollow-cylindrical gradient coil system of a magnetic resonance apparatus that has shim receptacles with a cross section having the shape of an annular segment, that are continuous in the axial direction. Corresponding shim trays are thereby insertable into the shim tray receptacles, the length of the shim trays being equal to a length of the gradient coil system and the shim trays being subdivided into corresponding shim pockets for the acceptance of ferromagnetic laminae.

Further, for example, U.S. Pat. No. 5,786,695 discloses that the introduction and removal of shim trays filled with shim laminae into or out of shim tray receptacles must ensue with the basic magnetic field turned off according to regulations. If the introduction and removal were to be undertaken inadvertently with the basic magnetic field turned on, then the shim tray disclosed in U.S. Pat. No. 5,786,695 is fashioned such that a cover of the shim tray is secured against the forces at the rest of the shim tray acting on the shim laminae.

Particularly in the case of a magnetic resonance apparatus having a tunnel-shaped examination space, a support mechanism can be introduced into and removed from the examination space through a first opening of the end of the space. Adequate space adjoining the first opening must be provided for an installation room of the magnetic resonance apparatus, so that a complete removal of the support mechanism from the examination space can be unproblemmatically implemented. By contrast, the magnetic resonance apparatus can be constructed with a second opening of the examination space lying opposite the first opening that has a comparatively small distance from a limiting surface of the installation room. In many instances, this prevents installation of shim trays that, corresponding to the length of the gradient coil system, have a length of one meter or more proceeding from a side of the second opening. So that the shim trays can be introduced regardless of the installation condition, the magnetic resonance apparatus together with the movable support mechanism usually is designed such that introduction is possible proceeding from the side of the first opening.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a shim tray, a gradient coil system and a magnetic resonance apparatus for the acceptance of the shim tray such that, among other things, a maximized volume is available for shimming.

This object is achieved by a shim tray fashioned with a cross-section corresponding to an annular segment for insertion into a shim tray receptacle, and wherein for the acceptance of shim laminae, the shim tray has at least one shim pocket having a cross-section corresponding to a rectangle, and wherein the shim tray is fashioned such that, for achieving a maximum area content of the rectangle, the rectangle is arranged within the annular segment such that a circumferential line of the rectangle touches a circumferential line of the annular segment in exactly three points.

As a result and compared to conventional shim tray receptacles and shim trays, either a greater maximum shim effect can be achieved given the same available space for shim tray receptacles, or the space required for shim tray receptacles can be reduced given the same maximum shim effect.

In an embodiment, the shim box is divided in a direction of insertion into at least two shim sub-boxes that can be released from one another. As a result thereof, an insertion and removal of the sub-boxes filled with shim laminae into or out of the shim box receptacle can be implemented as a normal procedure when the basic magnetic field to be shimmed is activated. The reason for this is that, compared to a comparable, undivided shim box, the magnetic forces acting on the sub-boxes only amount to a fraction. Advantageously, thus, a shut-down of the basic magnetic field is not necessary for the introduction and removal of the sub-boxes. The introduction and removal of the sub-boxes can be implemented with a comparatively slight exertion of force and can be supported by a suitably designed device. With the basic magnetic field activated, further, the sub-boxes filled with shim laminae can be carried or transported past a basic field magnet generating the basic magnetic field in the influencing region of the basic magnetic field, for example at a distance of approximately 50 cm. As a result, a general risk of accidents is reduced. Compared to a comparable, undivided shim box, further, the space required for the introduction and removal of the sub-boxes is significantly reduced, for example a distance between an opening of the shim box receptacle and a wall of a shielded compartment. Due to the shortness of the sub-boxes, further, lower tool costs are incurred in the manufacture, and the sub-boxes can be manufactured with a higher precision.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section through a portion of hollow-cylindrical gradient coil system with a shim tray receptacle having an annular segment-shaped cross-section in accordance with the invention.

FIG. **2** shows the portion of the gradient coil system of FIG. **1** with a shim tray inserted into the shim tray receptacle.

FIG. **3** is a perspective view showing a basic box unit of the shim tray of FIG. **2**.

FIG. **4** is a cross-section through a portion of a hollow-cylindrical shaped gradient coil system having a shim tray receptacle with a rectangular cross-section according to the prior art.

FIG. **5** shows the portion of the gradient coil of FIG. **4** with a shim tray inserted into the shim tray receptacle according to the prior art.

FIG. **6** is a perspective view showing a basic box unit of the shim tray of FIG. **5** according to the prior art.

FIG. **7** is a longitudinal section through a magnetic resonance apparatus with a shim tray composed of three sub-boxes.

FIG. **8** is a perspective view of sub-boxes that are connectable to one another as a result of their shaping.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As an exemplary embodiment of the invention, FIG. **1** shows a cross-section through a portion of a hollow-cylindrical gradient coil system **10** having a shim tray receptacle **12** that has a continuous, unchanging cross-section in the axial direction that corresponds to an annular segment **17**. The gradient coil system has an inside radius **21** of approximately 700 mm and an outside radius **25** of approximately 900 mm. A hollow-cylindrical region **11** indicated with broken lines inside the gradient coil system **10**, having an inside radius **22** of approximately 800 and a thickness **29** of approximately 22 mm, is provided for forming a shim tray receptacle **12**. (Multiple receptacles **21** are formed in the complete gradient coil system **10**) The hollow-cylindrical region **11** is arranged between the gradient coils at one side and the shield coils arranged farther toward the outside at the other side. Further, the gradient coil system **10** is cast with casting resin and includes parts of a cooling device as well as parts of an active shim system.

As an exemplary embodiment of the invention, FIG. **2** shows the portion from FIG. **1** with a shim tray **13** inserted into the shim tray receptacle **12**, the shim tray **13** having a basic box unit **14** that can be closed with a cover **15**. The shim tray **13** has shim pockets **16**, each of the shim pockets **16** having a cross-section corresponding to a rectangle **18**. Each of the shim pockets **16** can be maximally filled with shim laminae up to a height **19**. The shim tray **13** is fashioned such that, given a maximum area content of the rectangle **18**, the rectangle **18** is arranged within the annular segment **17** so that a circumferential line of the rectangle **18** touches a circumferential line of the annular segment **17** at exactly three points.

FIG. **3** shows a portion of the basic box unit **14** of FIG. **2** without the cover **15** and in a perspective view. The basic box unit **14** is subdivided into the shim pockets **16** in the axial direction that can be filled with shim laminae of magnetic material according to the inhomogeneities of the basic magnetic field to be corrected.

For comparison, FIG. **4** shows a cross-section through a portion of a known hollow-cylindrical gradient coil system **30** having a known shim tray receptacle **32**. The shim tray receptacle **32** has a continuous unchanging cross-section in the axial direction corresponding to a rectangle **32**. The description from FIG. **1** applies correspondingly for the radii of the gradient coil system as well as a hollow-cylindrical region **31** (indicated with broken lines) for shim tray receptacles.

For comparison, FIG. **5** shows the excerpt of FIG. **4** with a shim tray **33** inserted into the shim tray receptacle **32** according to the prior art. Like the shim tray receptacle **32**, the shim tray **33** comprises a cross-section corresponding to a rectangle **38**. The shim tray **33** has a basic box unit **34** that can be closed with a cover **35**. The length of the shim tray **33** approximately corresponds to the length of the gradient coil system **30**. Filling of the shim tray **33** with shim laminae of magnetic material is thereby maximally possible to a height **39**.

Again for comparison, FIG. **6** shows a portion of the basic box unit **34** of FIG. **5** without the cover **35** and in a perspective view. The basic box unit **34** is subdivided in the axial direction into shim pockets **36** that can be filled with a number of shim laminae of magnetic material according to the inhomogeneities of the basic magnetic field to be corrected until the maximum height **39** has been reached.

Given the same thickness **29** of the hollow-cylindrical regions **11** and **31**, the fashioning of the shim tray **13** and of the shim tray receptacle achieve a volume available for shim laminae, particularly an available height **19**, is enlarged compared to a height **39** available in the prior art, and inhomogeneities of the basic magnetic field thus can be corrected over a broader scope.

In another embodiment for achieving an identical maximum shim effect, the hollow-cylindrical region **11** can be implemented with a lower thickness **29** compared to the region **31**, so that, for example, an examination space with a larger diameter can be achieved in a magnetic resonance apparatus or, when the diameter of the examination space remains the same, an inside diameter of a hollow-cylindrical basic field magnet can be made smaller, which yields considerable cost advantages, particularly in the case of a superconducting basic field magnet.

As an exemplary embodiment of the invention, FIG. **7** shows a longitudinal section through a magnetic resonance apparatus with a shim tray **73** composed of three sub-boxes **74**, **75**, **76**. For generating a static, optimally uniform basic magnetic field within a spherical homogeneity volume **83** of the magnetic resonance apparatus, the magnetic resonance apparatus has a superconducting, essentially hollow-cylindrical basic field magnet **81**. For generating gradient fields, the magnetic resonance apparatus has a likewise essentially hollow-cylindrical gradient coil system **70** that is arranged in a hollow of the basic field magnet **81**. A hollow opening of the gradient coil system **70** essentially forms the limitation of a tunnel-shaped examination space **87**. For introducing an examination subject, for example a patient **80**, into the examination space **87**, the magnetic resonance apparatus has a movable support mechanism **82** that is secured to the basic field magnet **81**.

The components **70**, **81** and **82** of the magnetic resonance apparatus described above are arranged in a shielded compartment **84**. A first opening **88** of the tunnel-shaped examination space **87** through which the support mechanism **82** can be moved in and out, has a spacing from a left wall **85** of the shielded compartment **84** so that the support mechanism **82** can be completely moved out of the examination space **87**. Thus, the patient **80** can lie or can be placed comfortably onto the support mechanism **82**. By contrast, a second opening **89** of the tunnel-shaped examination space **87** lying opposite the first is arranged at a distance from a right wall **86** of the shielded compartment that only allows the support mechanism **82** to be moved out so far through the second opening **89** that, for example, whole-body imagings and/or angiographies of peripheral vessels of the patient **80** can still be implemented.

Further components of the magnetic resonance apparatus, for example a radio-frequency antenna arranged in the hollow of the gradient coil system **70**, are not shown since they are well known.

The gradient coil system **70** has at least one shim tray receptacle **72** into which shim trays **73** composed of the three sub-boxes **74**, **75**, **76** that are releasable from one another can be introduced proceeding from the side of the second opening **89**. Each of the sub-boxes **74**, **75** and **76** and the gradient coil system **70** are fashioned corresponding to the shim tray **13** and gradient coil system **10** shown in FIGS. **1** through **3** or corresponding to the shim tray **33** and gradient coil system **30** shown in FIGS. **4** through **6**.

The tripartite division of the shim tray **73** is designed such that the middle sub-box **75** that is arranged in the region of the homogeneity volume **83** is optimally long for a good compensation of inhomogeneities within the homogeneity volume **83** and all sub-boxes **74**, **75** and **76** are designed such that they can be introduced proceeding from the side of the second opening **89**. Thus, they can be introduced into and removed from the shim tray receptacle **72** when filled with shim laminae and with an activated basic magnetic field and can be carried past the basic field magnet **81** within the shielded compartment with the basic magnetic field activated.

Introduction is enabled due to the tripartite division of the shim tray **73** only because of the slight distance between the second opening **89** of the examination space **87** and the right wall **86** of the shielded compartment. Since a possible introduction of shim trays proceeding from the side of the first opening **88** need not be taken into consideration in the design of the support mechanism **82**, new degrees of design freedom—among other things—advantageously exist for the support mechanism **82** secured to the basic field magnet **81**.

FIG. **8** shows a perspective view of sub-boxes **77**, **78** and **79** that are connectable to one another on the basis of their shaping, so that, for example upon introduction into a shim tray receptacle, the sub-boxes **77**, **78** and **79** can be assembled inter-engaging with one another. The shaping is designed at the longitudinal ends of the sub-boxes **77**, **78** and **79** so that the sub-boxes **78** and **79** are also pulled along toward the left in longitudinal direction out of the shim tray receptacle together with a pulling of, for example, the sub-box **77**.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

We claim as our invention:

1. A shim tray adapted for insertion, in an insertion direction, into a receptacle shaped as an annular segment, and wherein said shim tray has a cross-section corresponding to said annular segment, and wherein said shim tray contains at least one pocket adapted to receive shim lamina, said pocket having a cross-section corresponding to a rectangle, and wherein said shim is adapted to be received within said receptacle with a circumferential line of said rectangle touching a circumferential line of said annular segment in exactly three points for giving said rectangle an area that is maximum within said cross-section.

2. A gradient coil system comprising a receptacle shaped as an annular segment and a shim tray insertable into and removable from said receptacle, said shim tray having a cross-section corresponding to said annular segment, and wherein said shim tray contains at least one pocket adapted to receive shim lamina, said pocket having a cross-section corresponding to a rectangle, and wherein said shim tray is received within said receptacle with a circumferential line of said rectangle touching a circumferential line of said annular segment in exactly three points for giving said rectangle an area that is maximum within said cross-section.

3. A gradient coil system as claimed in claim **2** shaped as a hollow cylinder having a longitudinal cylinder axis, and wherein said receptacle has an unchanging cross-section along said longitudinal axis.

4. A magnetic resonance apparatus comprising a receptacle shaped as an annular segment and a shim tray insertable into and removable from said receptacle, said shim tray a cross-section corresponding to said annular segment, and wherein said shim tray contains at least one pocket adapted to receive shim lamina, said pocket having a cross-section corresponding to a rectangle, and wherein said shim tray, for a maximum area content of said rectangle, is received within said receptacle with a circumferential line of said rectangle touching a circumferential line of said annular segment in exactly three points for giving said rectangle an area that is maximum within said cross-section.

5. A magnetic resonance apparatus as claimed in **4** having an examination space accessible from two sides, a support mechanism movable into and out of said examination space from a first of said sides, and wherein said shim tray is insertable into and removable from said receptacle from a second of said sides.

6. A magnetic resonance apparatus as claimed in claim **5** comprising a basic field magnet, and wherein said support mechanism is mounted to said basic field magnet.

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